`

RHEOLOGICAL BEHAVIOR OF SOFT FLOUR IN PRESENCE OF OIL AND SURFACTANT

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By

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CERTIFICATE

This is to certify that B.Tech. (Research) thesis entitled, "**RHEOLOGICAL BEHAVIOR OF SOFT FLOUR IN PRESENCE OF OIL AND SURFACTANT"** submitted by **Deepika Tew** in partial fulfillment for the requirements of the award of Bachelor of Technology degree in Chemical Engineering at National Institute of Technology, Rourkela is an authentic work carried out by her under my supervision and guidance. She has fulfilled all the prescribed requirements and the thesis, which is based on candidate's own work, has not been submitted elsewhere.

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CONTENTS

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Abstract

The rheological behaviour of soft flour (maida), a source of wheat starch was studied. Without any additives, flour solution showed thixotropic behaviour and its viscosity increased with the increase in the flour concentration. The addition of additives like oil and surfactant altered the rheological properties of flour-water suspension. The rheological properties have been studied in the presence of oil. It was found that the viscosity decreased slightly with the addition of oil. It showed shear-thinning behaviour of flour. To attain the stability of flour-water-oil solution, a non-ionic surfactant was used and change in viscosity was investigated. It showed shear thinning behaviour and at constant shear rate, it showed thixotropic behaviour.

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Chapter 1

Introduction

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1.1 Introduction

Starch is widely used in the food industry [1]. It is used as a thickening agent and provides moisture control and water mobility [2]. Therefore, it improves the overall product quality, reduce cost and/or facilitate the processing. Starch pastes rheology analysis allows predicting its behaviour during thermal treatment, which is important for application in food industry. In a real fluid, the relationships between the shear stress and shear rate are part of the science of rheology. Soft flour (flour) can form 3-dimensional viscoelastic dough when mixed with water. The baking performance of flour is mainly governed by the dough rheology. The non-linear viscoelastic behaviour of flour dough are basically due to the presence starch fraction [3].

1.2 Rheology

Rheology is the flow of matter and deformation. During rheological measurements, a material is deformed and the force exerted and the deformation achieved is measured. Rheology is mainly considered for liquids, soft solids or solids under the condition in which they flow rather than deform elastically. It is exhibited by the substances having a complex structure, including suspensions, polymers, muds, foods and other biological materials.

1.2.1 Newtonian Fluid

Liquids with flow properties obeying Newton hypothesis are Newtonian fluid or Newton-Stokes liquid. In the Newtonian fluid, shear stress varies linearly with strain rate and, therefore, gives constant viscosity. In wide temperature and pressure ranges, most common fluids such as water, organic solvents, steam, oil, air, nitrogen and rare gases follow Newtonian[4] behaviour.

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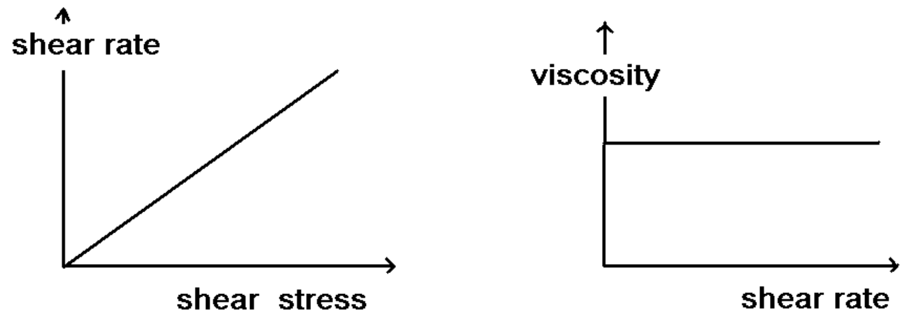

Figure 1.1: Relationship between shear stress and shear rate and the viscosity at varying shear rate

1.2.2 <u>Non- Newtonian Fluid</u>

A non-Newtonian fluid is a fluid whose viscosity varies with the applied stress or force. The most common examples are starch suspensions, ketchup, toothpaste, paint and shampoo. The relation between shear stress and strain rate is non-linear and even be time-dependent. Therefore, a constant coefficient of viscosity cannot be defined.

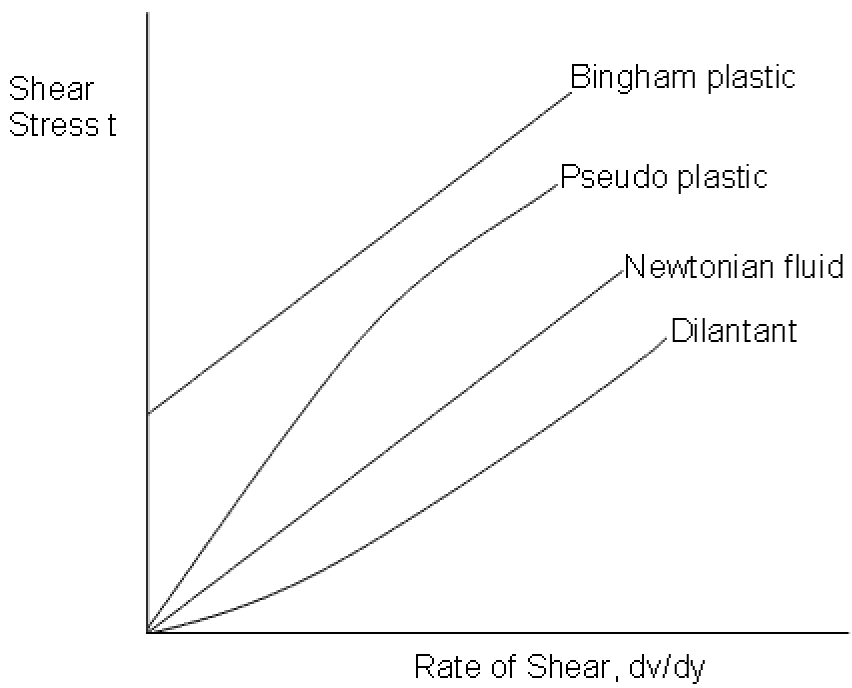

Figure 1.2: Shear stress Vs. Shear rate plot for different types of fluids

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1.3 Surfactant

Surfactants are water soluble surface active agents [4]. Surfactants have two portions i.e. hydrophilic portion (solubility enhancing functional group) and the hydrophobic portion (usually a long alkyl chain). Depending on the charge of the head group, the surfactant is classified as anionic, cationic, non-ionic and amphoteric/zwitterionic surfactants.

- Anionic Surfactant

  The head is negatively charged in solution. This surfactant is used in dishwashing liquids, shampoos and laundry. The most common examples of anionic surfactants are alkyl sulphates, alkyl ethoxylate sulphates and soap.

- Cationic Surfactant

  The head is positively charged in solution. The cationic surfactant provides softness in fabric softener and in detergents with build-in fabric softener. They are good the emulsifying agent. They do not form insoluble scum when in contact with hard water ions. The most commonly used cationic surfactants are

- Non- ionic Surfactant

  This type of surfactant does not possess any electrical charge. These are not 0sensitive to hard water and well suited for cleaning purposes. The most commonly used non-ionic surfactants are fatty alcohol poly glycosides, alcohol ethoxylates etc.

- Amphoteric/zwitterionic Surfactant

  The charge of the hydrophilic part for the amphoteric surfactant is controlled by the pH of the solution. So, they can act as a cationic surfactant in acidic solution and an anionic surfactant in alkaline solution.

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1.4 Applications

- Properties of the starch present play a vital role in each and every process of the bakery industry. Gluten is the main factor in determining the rheological and gas holding properties of bread dough.
- A detergent used for cleaning purposes is a surfactant or a mixture of surfactants.
- Starch nanoparticles or nano gels are widely used in the construction of nanoscale sensors, mechanical devices and drug delivery systems.
- Starch is used in the paper industry to make the paper stronger.

1.5 Objective

The objective of the work has been listed as follows:

- To study the rheological behaviour of flour slurry for different flour concentration.
- To study the effect of shear rates on the viscosity of flour solution.
- To study the effect of different concentration of oil on the viscosity of flour solution.
- To study the effect of non-ionic surfactant on the viscosity of flour solution.

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CHAPTER 2

LITERATURE REVIEW

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2.1 Studies on the effect of oil

Determination of the viscosities of starch pastes is of great importance. The water phase is a solution of highly functional hydrocolloids, e.g. food starch or gums and oil phase is terpenes, vegetable oil or flavour oil. But due to the difference in specific gravity between the oil droplets and water medium, these types of oil in water emulsion are inherently unstable [6]. The changing oil concentration did not have any significant effect on the viscosities under the conditions as applied shear rate during the study. Small fluctuations were present in the values of measured viscosities of the starch pastes.

Different types of oil are used in food industry as a flavouring agent in the final stages of cooking. The addition of increasing amount of oil results in decreased viscosity [7].With the increase in starch content, the starch network develops gradually resulting in enhanced rheological nonlinearity with narrowing of viscoelastic range under shear action [8]. These measurements in the estimations can be clarified by the way that the temperatures extend over which the estimations were performed, was near to the peak viscosity of the gelatinization period. Increasing the oil concentration in the emulsion leads to an increase in consistency index k and decrease in flow behaviour index n showing shear thinning behaviour. The starch pastes show power law behaviour with n ranging from 0.97 to 0.995[9].

2.2 Studies on the effect of surfactant

From the literature, it can be found that the addition of surfactant to the starch significantly changes the viscosity. Stability of oil-in-water emulsions can be achieved by the addition of surfactant. Due to the macromolecular nature of the surfactant, it has a significant influence

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on the viscosity of continuous phase. The influence of sodium dodecyl sulphate (SDS) concentration on the rheological characteristics of oil-in-water emulsion has been investigated [10]. It was found that with the increase in the amount of SDS in the emulsion mixture, the apparent viscosity decreased but changes in SDS concentration haven't shown any dependency on the flow behaviour index. From Table 1 it was found that on increasing the amount of SDS in the mixture of SDS and OSA starch led to a decrease in consistency index K which means decrease in apparent viscosity.

Table 2.1: Flow curves parameters *K* and *n* of the emulsions stabilized with OSA starch and OSA starch–SDS mixtures [10]

Oil content, %	(cOSA starch + cSDS), %	K/ Pas	n
5	10+0	0.0088990 ± 0.00016	0.9463667 ± 0.00588
	9+1	0.0088623 ± 0.00041	0.9772000 ± 0.00578
	7+3	0.0070097 ± 0.00032	0.9533667 ± 0.00745
	5+5	0.0042753 ± 0.00005	0.0042753 ± 0.00005
20	10+0	0.0216700 ± 0.00342	0.9314000 ± 0.00375
	9+1	0.0209600 ± 0.00038	0.9300667 ± 0.00428
	7+3	0.0190533 ± 0.00076	0.8834333 ± 0.00373
	5+5	0.0103467 ± 0.00048	0.9095333 ± 0.00621
50	10+0	0.2717333 ± 0.01986	0.7781333 ± 0.01249
	9+1	0.2010000 ± 0.01288	0.7586000 ± 0.01102
	7+3	0.7586000 ± 0.01102	0.7423000 ± 0.01032
	5+5	0.1094000 ± 0.02085	0.7815333 ± 0.02315

Additives like surfactant improve the quality of bread but fewer research works were done on the effect of these additives on the rheological properties of dough. Mono-diglyceride and lecithin are used as surfactants in this literature [11]. It was found that with the addition of

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these additives the water percent absorption increased significantly which is important for the economical point of view. Surfactants also retarded the staling of bread.

In Mira et al. the effect of surface active agents on the wheat starch and waxy wheat starch in aqueous suspension was studied. The extent of the changes was found to be different for the different surfactants. From the shape of pasting curves, the presence of surfactant exhibits a more homogenous behaviour and swelling over a narrower temperature range [12].

The complexes are formed between surfactants and the helical chain of amylopectins. Non-ionic surfactant contains both hydrophobic and hydrophilic group which enhances the gelatinization and swelling processes of starch granules.

The hydrophobic group tends to form a linear chain with amylopectin and complexes with the amylase. The hydrophilic group help in the formation of the complex by making the approach the hydrophobic groups into the hydrated molecular chains.

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CHAPTER 3

Materials and Methods

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3.1. Introduction

This chapter explains the conceptual study, laboratory experimental work, analysing and completion of the project. The detailed procedure of the experimental work is discussed throughout this chapter. In general, the experiment consists of two major section, laboratory work and data analysis.

3.2. Materials

Commercial soft wheat flour (flour) was purchased from the local market and was used as a source of starch. Commercially available sunflower oil was added to the flour solution at different quantity, 0-20% (w/w). A non-ionic surfactant (IGEPAL CO 630) with 1 mM concentration was added to the different concentrations of flour-water-oil slurry.

Table 3.1: Properties of IGEPAL CO 630 (non-ionic surfactant)

Related Categories	Material science, Micro/Nano Electronics, Non-ionic, Non-ionic surfactants, Polymer additives
Molecular weight	Average M_n 617
Boiling point	250^oC (lit.)
Density	1.056 g/mL at 25^oC (lit.)
HLB	13

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3.3. Methods

Flour dispersion in water was prepared by mixing. Rotational cone and plate BOHLIN VISCO-88 viscometer was used for viscosity measurement. The diameter of the cone was 30 mm and angle was 5.4°. For every measurement, a gap of 0.15 mm was maintained between cone and plate of the viscometer. Viscosity was measured over a range of shear rates (19.342 s^{-1} to 103.16 s^{-1}). The viscosity of the flour dispersion without additives containing 50%, 60%, 70% and 80% (by w/v %) were quantified at variable shear rates as well as at constant shear rate of 19.342 s^{-1}. The slurry in the presence of different oil concentration (5%, 10% and 15% w/v %) was prepared and viscosity was measured at variable shear rates as well as at constant shear rates. To attain the stability of the oil, water and flour solution desired amount of non-ionic surfactant IGEPAL CO 630 was added to the slurry and viscosity of the samples were measured at a constant shear rate of 19.342 s^{-1}.

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Chapter 4

Results and discussion

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4.1 Introduction

Rheology focuses on the flow properties of complex fluids. Unlike solids, fluids undergo deformation continuously when stress is applied. Determination of viscosities of starch pastes is of great importance and has a wide range of application.

4.2 Effect of starch concentration

Four dissimilar concentrations of flour (50%, 60%, 70% and 80% by w/v %) were taken and rheological behaviour was studied. The curve was obtained by changing the shear rate from 19.342 s^{-1} to 103.16 s^{-1}. It was noticed that with the increase in shear rate, the stress increases and viscosity decreases. From the curve, it is noticed that the slurry shows non-Newtonian behaviour and pseudo plastic behaviour. It can be seen that viscosity is a function of shear rate.

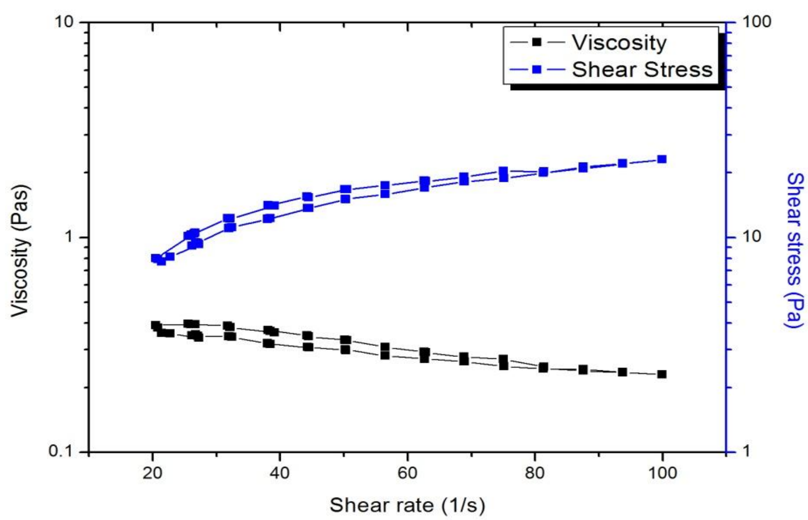

Figure 4.1 (a): Variation of Shear stress and Viscosity with respect to Shear rate for 50% (w/v %) flour concentration

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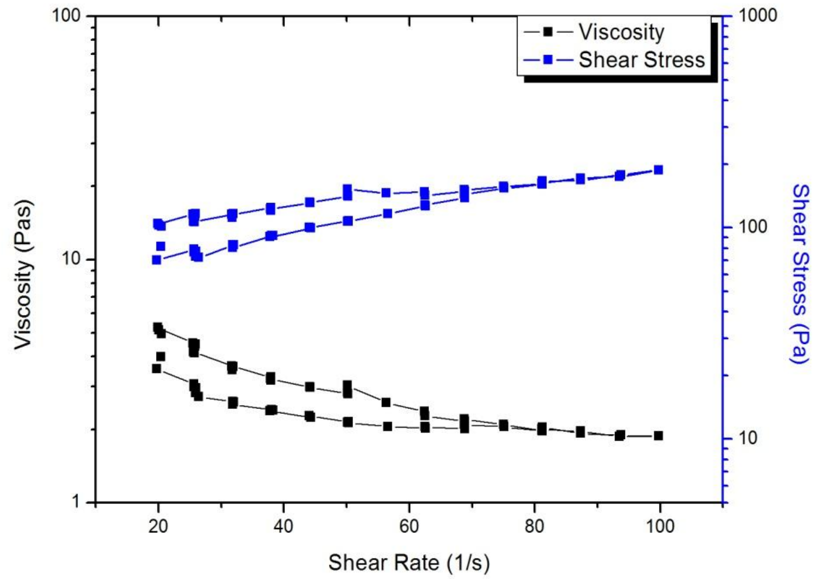
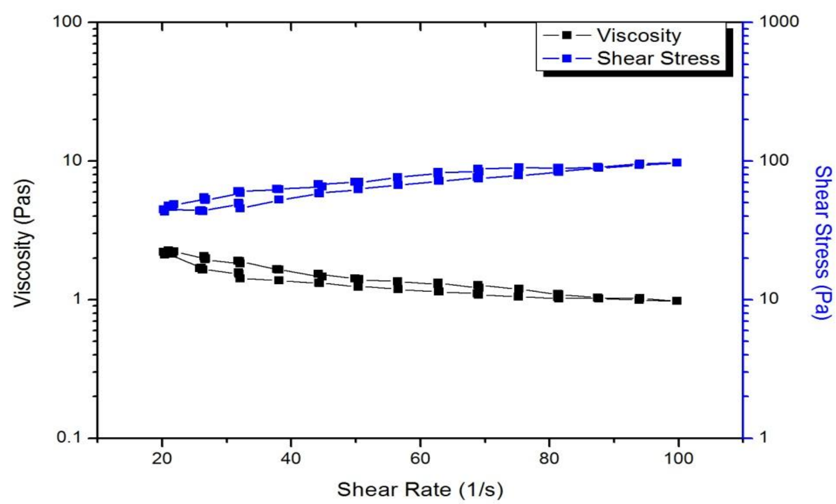


4.1 (b): Variation of Shear stress and Viscosity with respect to Shear rate for 60% (w/v) flour concentration



4.1 (c): Variation of Shear stress and Viscosity with respect to Shear rate for 70% (w/v %) flour concentration

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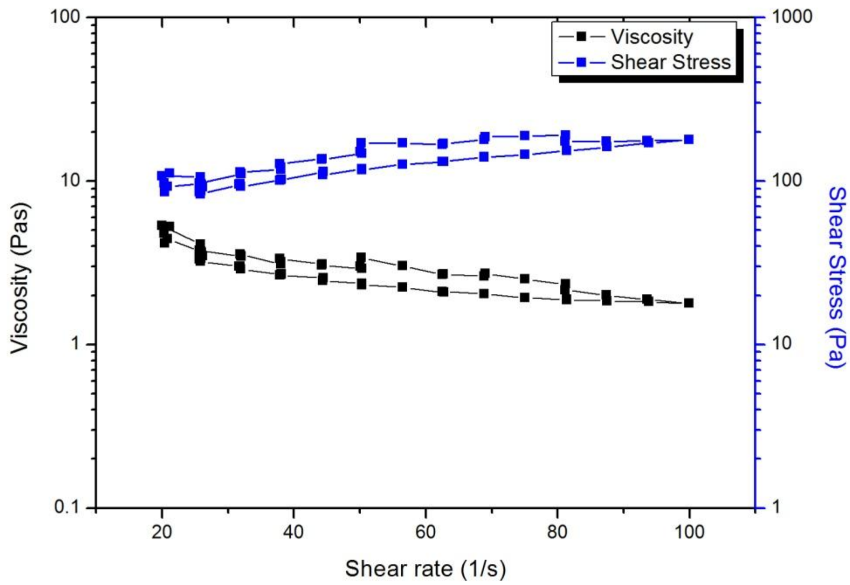

Figure 4.1 (d): Variation of shear stress and viscosity with respect to shear rate for 80% (w/v %) flour concentration

At 19.342 s^{-1}, viscosities of different concentration of flour slurry were studied. It was observed that with the increase in concentration, the viscosity increased non-linearly.

4.3 <u>Effect of oil on viscosity</u>

On the addition of oil to the flour slurry, the viscosity decreased with the increase in shear rates resulting in shear thinning behaviour. It was noticed that on increasing the oil concentration to the flour slurry, there was a slight decrease in viscosity for the constant shear rate.

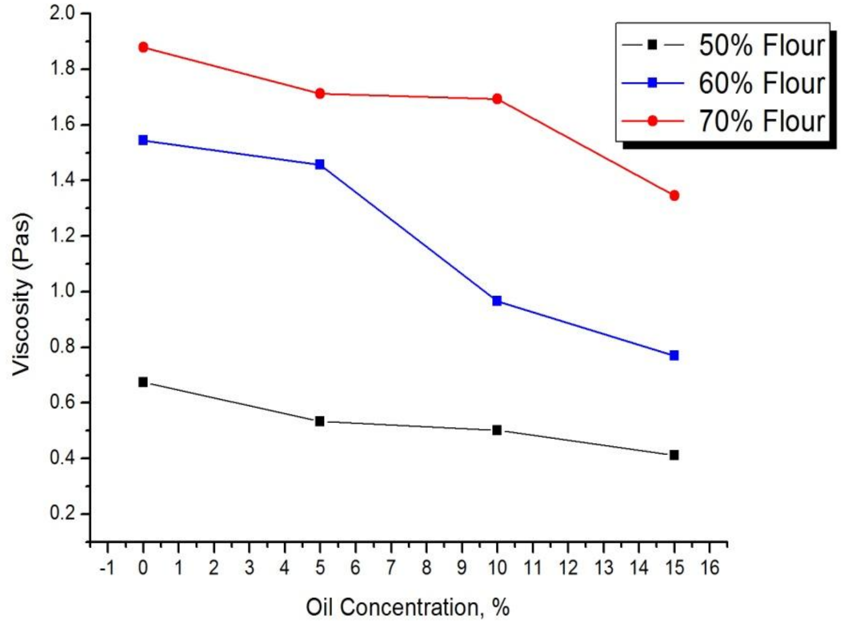

Figure 4.2: Variation of viscosity and oil concentration at constant shear rate of 19.342 s^{-1}

On comparing with the results with the flour concentration without any additives, it was found that there was a very slight change in viscosity of the flour slurry with oil added to it.

4.4 Effect of surfactant on viscosity

The surfactants are known for improving the rheological properties of starches. The viscosity decreased significantly when compared to the samples without addition of the surfactant. The sample with 50% flour and surfactant haven't showed any result in the viscometer due to the formation of a true solution and the absence of viscous paste. Figure 4.3 illustrates and compares the change in viscosity of different concentration of flour with and without additives.

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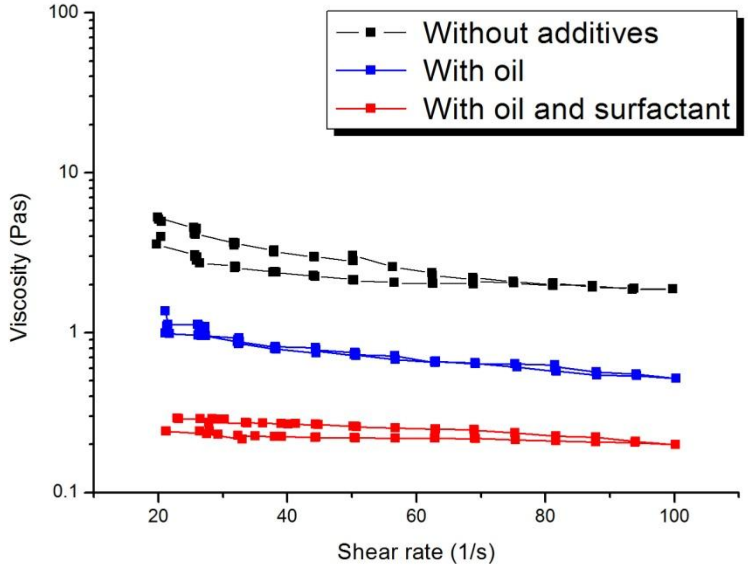

Figure 4.3 (a): Variation of viscosity and shear rate for 60% flour concentration with and without additives

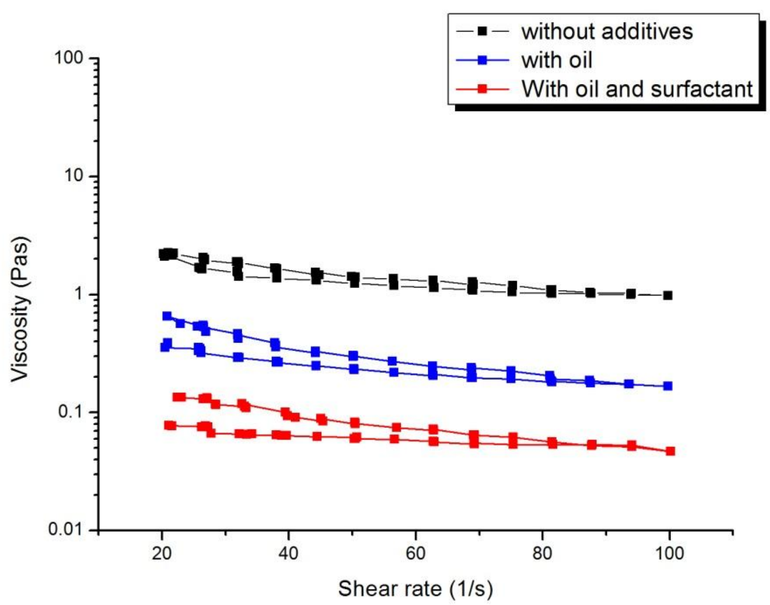

Figure 4.3 (b): Variation of viscosity and shear rate for 70% flour concentration with and without additives

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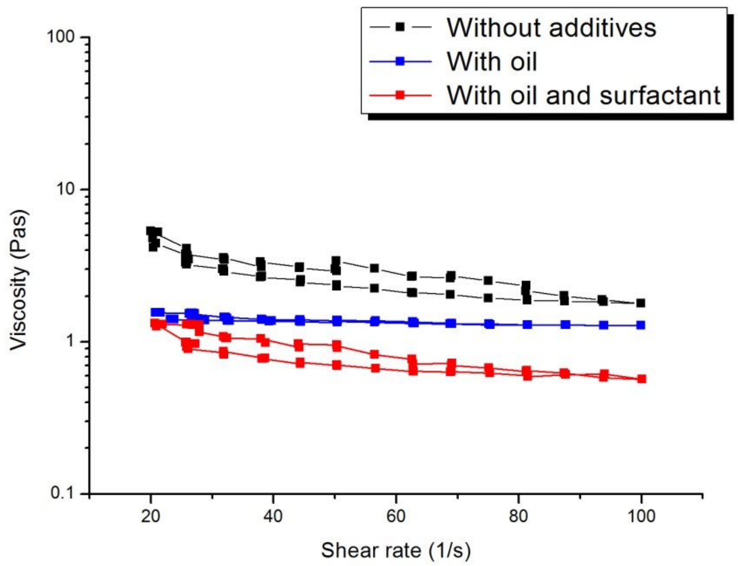

Figure 4.3 (c): Variation of viscosity and shear rate for 80% flour concentration with and without additives

The significant change in the viscosity of the flour solution is due to the adsorption of surfactant on the surface of the solution. With the addition of surfactant the water absorption of the flour solution suddenly increased and maximum resistance decreased.

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Chapter 5

Conclusion

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5.1 Conclusion

Rheological behaviour of soft flour, a source of wheat starch is found out. From the results obtained we have, in aqueous medium viscosity increases with the weight percentage of flour. At constant flour concentration, the viscosity decreases with the increase in shear rate showing shear thinning behaviour. In case of oil, as the concentration of oil increases there is a little decrease in viscosity. But in the presence of both oil and surfactant in the flour slurry resulted in significant decrease in viscosity. The viscosity decreases from the individual viscosity value of solution without any additives.

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